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Optically Exciting a Magnetic Memory: A Feasibility Study

A study has been made to determine the feasibility of modifying the magnetic moment of a magnetically ordered material by optical pumping for application to digital memories.

The potential of optically addressed (often referred to as beam addressable) digital memories has been considered by a number of workers and is presently an area of much research. The goal to which these efforts are directed is the achievement of high-density bulk memory with storage capacity of approximately 10^8 bits. This density can be achieved in reasonable size, for example a planar area of 10 × 10 cm, with bit resolution of 10 microns. Such a bit size is about an order of magnitude larger than diffraction-limited resolution of visible light. Thus, optical approaches appear attractive. In addition, the interaction of polarized light with magnetic materials exhibiting the magneto-Kerr effect and Faraday effect provides a means for detecting the magnetization state of a local region via reflection or transmission providing communication with the "store" without interconnecting wires.

The limiting operation, however, in all presently proposed memory schemes is the write process. This has generally been accomplished by applying heat to the lattice in order to effect a change in coercivity of a local spot. The heat source may be a laser or electron beam; both have been proposed and experimentally studied. The use of temperature changes to modify the magnetic state of a memory medium introduces speed performance limitations. In addition to the relatively long thermal time constants, another problem associated with thermal excitation is that of thermal creep. In order to prevent adjacent bit disturbing effects it appears necessary to provide thermal barriers between storage element locations. This results in a reduction of achievable storage density and increases the fabrication process complexity. To overcome these limitations associated with thermal excitation, the study sought to determine the feasibility of optically pumping a magnetic material to effect the switching process. This approach provides the potential of achieving excitation and decay times in the sub microsecond range without the problem associated with thermal creep. The experimental work to date has been directed toward the rare earth iron garnets. These materials show a rapid change in coercive force versus temperature at the antiferromagnetic compensation temperature. This effect is attributed to the fact that slight variations in temperature cause a net magnetic moment to exist. A technique is therefore being sought for holding the lattice temperature constant while the magnetic moment is changed by optical excitation.

It is apparent from the study to date that the gadolinium iron garnet crystals grown by the present molten flux technique will not exhibit the desired characteristics. The conduction band causing the large competing absorption is probably a characteristic of the iron-oxygen combination rather than impurity-induced interband gap levels. As such, the rare earth garnets are all limited by this absorption edge. Only terbium and dysprosium offer a possibility of pumping at energies below the conduction band edge. Antiferromagnets overcome the problem of lattice phonons creating uncompensation, but little is known of the optical properties of the potentially useful materials.

The concept of uncompensating an antiferromagnetically ordered system is of significant interest both theoretically and practically. The significance of achieving 10^8 bit high-speed random access computer

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memories with passive element reliability should not be understated. Optical pumping is considered a powerful approach towards achieving that goal.

Note:

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